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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in Transducer Arrangements

We, CREED & COMPANY LIMITED, a British Company, of Telegraph House, Croydon, Surrey, England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to improvements in transducer arrangements.

It is an object of the present invention to provide a transducer arrangement of improved design and having improved operating characteristics. Embodiments of the arrangement are suitable for a wide variety of applications and each is especially, although not exclusively, suitable for use in telegraph apparatus.

According to the present invention therefore there is provided a transducer arrangement including electro-magnetic means and a piezo-resistive device, said piezo-resistive device being electrically isolated from and mechanically coupled to said electro-magnetic means so that on energisation of the electro-magnetic means the mechanical coupling causes a resistance change to be effected in the piezo-resistive element of said device.

The invention will be better understood from the following description read with reference to the accompanying drawings in which:

Figs. 1 to 7 show various embodiments of the invention,

Fig. 8 shows an electric circuit including a piezo-resistive device incorporated in any one of the embodiments of the invention shown in Figs. 1 to 7 inclusive.

The embodiment of Fig. 1, comprises a plate 1 on which there is mounted, by well-known means, an electro-magnet 2. The coil 3 of the electro-magnet 2 is connected, via terminals 'T1", to a D.C. signal source, whilst the armature 4 thereof is pivotally mounted on a pin 5 extending from the plate 1. The armature 4 is biassed to pivot, in a clockwise direction, to rest against the right-hand one of two stop pins 20, by a tension spring 10 which is affixed at its ends to the armature 4 and to a pin 11 extending from the plate 1. Between the upper end of the armature 4 and a mounting block 6 extending from the plate 1, there is connected a piezo-resistive device comprising a mounting strip 7 and a piezo-resistive element 8 of a well-known type. This element is of, for example, silicon and is rigidly connected to the mounting strip 7 at its end portions. Electrical connections in the form of lead-wires 9 connect the element to the terminals "T2", which terminals may in turn be connected to associated electric circuitry.

On application of an energising current to the coil 3 of the electro-magnet 2 from a D.C. signal source via terminals "T1", the armature 4 of the electro-magnet is attracted to the core thereof against the influence of the tension spring 10, until it engages with the left-hand one of the stop pins 20. In the attracted condition of the armature, the armature and the piezo-resistive device assume the positions shown in dotted outlines. This attraction of the armature 4 causes deformation of the strip 7 which then imposes a strain on the piezo-resistive element 8. This strain, in turn, causes a change in the resistance of the piezo-resistive element 8, so that the electrical resistance between the terminals T2 changes. This change can be detected by electric circuitry to which the element is connected. A change in the resistance of the piezo-resistive element 8, through movement of an armature, is effected in each of the

[*Price 4s. 6d.*]

embodiments now to be described with reference to Figs. 2 to 5.

The embodiment of Fig. 2 is a modified version of that shown in Fig. 1. In this version the pivot pin 5, tension spring 10 and the pin 11 are dispensed with, and the armature 4 is secured at its upper end to the mounting strip 7. In the position shown in full lines the armature 4 and the piezo-resistive device rests against the right hand one of the stop pins 20. The position shown in dotted outlines is the position to which the armature 4 and the piezo-resistive device move when the electro-magnet 2 is energised from the D.C. signal source via terminals "T1".

Referring now to Fig. 3, this embodiment has an electro-magnetic arrangement of two identical pole-pieces 12 and 13 interconnected by a magnet 14. There is an armature 4, surrounded by a coil 15, and which is pivotally mounted between the pole-pieces on a pin 16 extending from the plate 1. As in the previous embodiments, the mounting strip 7, carrying the piezo-resistive element 8, is connected by its ends to the upper end of the armature 4 and to the block 6 extending from the plate 1. The armature 4 and the piezo-resistive device can move to adapt either the position shown in full lines, or the position shown in dotted outlines, dependent on the flow of the energising current applied to the coil 15 on the armature 4 from the D.C. signal source via the terminals "T1".

The embodiments of Figs. 4 and 5 are modified versions of the embodiment of Fig. 3. The embodiment of Fig. 4 includes a pair of tension springs 10 connected between the upper end of the armature 4 and a pair of pins 11 extending from the plate 1. These springs normally maintain the armature 4 and the piezo-resistive device in the stable position shown in full lines, i.e. midway between the pole pieces 12 and 13. The armature 4 and the piezo-resistive device are arranged to move towards one or the other of the positions in which they are shown in dotted outlines dependent on the flow of the energising current applied to the coil 15 from the D.C. signal source via the terminals "T1".

The embodiment of Fig. 5 includes only one spring 10 between the upper end of the armature 4 and a pin 11. This spring maintains the armature 4 and the piezo-resistive device in the positions shown in full lines. In the energised condition of the coil 15, the armature 4 is attracted in such a manner that it, and the piezo-resistive device, move to adopt the positions shown in dotted outlines.

Referring now to the embodiments shown in Figs. 6 and 7, that which is shown in Fig. 6 comprises a plate 1 on which there is mounted, by well known means, an electro-magnet 17. The central leg 19 of the electro-magnet accommodates thereon a coil 18 which when connected to a suitable power source via the terminals T3, will energise the electro-magnet.

As in the previously described embodiments, the upper end of the strip 7 of the piezo-resistive device is affixed to the block 6, however in this embodiment the lower end of the strip is connected to a coil former 20, on which a coil 21 is wound. The former 20 for the coil 21 is arranged to surround a portion of the central leg 19 of the electro-magnet 17, but is free of contact therewith whether the electro-magnet is in an energised condition or not.

Energisation of the coil 21 from a D.C. signal source, via the terminals T1, subjects the coil 21 to a deflecting force, provided the electro-magnet is energised by the connection of coil 18 to a suitable power source via terminals T3.

This deflection in turn imposes a strain on the piezo-resistive device and causes a change in the resistance of the element 8, which change is manifest in electric circuitry in which the element is included

The embodiment of Fig. 7 differs from that of Fig. 6 only in that the magnetic flux in which coil 21 is immersed is due to a permanent magnet 19 instead of the energising coil 18. Energisation of the coil 21 from a D.C. signal source via terminals T1, has the effect of causing deflection of the coil 21, to impose a strain on the piezo-resistive device and to cause a change in the resistance of the element 8 thereof, as in the previously described embodiment.

There are many practical applications for each of the embodiments described herein, however any one of the embodiments described with reference to Fig. 1, 2, 4, 5, 6 or 7 is suitable for use as a telegraph receiver operating under the well-known on/off conditions of single current working. In its employment in this manner any one of the arrangements will perform the functions of electrically isolating the receiver as a whole (i.e. a teleprinter) from the telegraph line, and of translating the elements of a received code combinations of electric signals into changes in the resistance of the piezo-resistive element 8, which changes are then used, by associated electric circuitry, to register the "mark" and "space" conditions of the elements of code combinations of signals received serially on the telegraph line.

Fig. 8 shows the piezo-resistive element 8 of any one of the arrangements of Figs. 1 to 7 inclusive connected in an electric circuit to function as a telegraph receiver. The element S is electrically connected in series, via its terminals "T2", with a source of D.C. potential and a resistor "R1". A well-known form of utilisation device "UD",

responsive to a change in the magnitude and/or direction of electric current flow therethrough as a result of a change in the resistance of the element 8, is electrically connected between a datum potential and a point between the element 8 and the resistor R1 to register the condition of the telegraph line.

In single current working, the "mark" and "space" conditions of the elements of a code combination are represented by, respectively the presence or absence of a voltage on the telegraph line. The transmitted voltage may be, for example, 48 volts D.C. and it is always present on the line during standby periods in which the line is ready to pass traffic, i.e. messages between, for example, two co-operating teleprinters. With this voltage present on the telegraph line, the coil 3 of the arrangement of Fig. 1 or 2, or the coil 15 of the arrangements of Figs. 4, or 5 respectively will be energised. The armature 4 and the piezo-resistive element 8 of the arrangements of Fig. 1, 2 or 5 will be displaced and held in the positions in which they are shown in dotted outlines, and the armature 4 and the piezo-resistive device of the embodiment of Fig. 4 will be displaced from the stable positions in which they are held by the springs 10 towards one or other of the positions in which they are shown in dotted outline, dependent on the direction of current flow through the coil 15. In each case the piezo-resistive element will be in a state of strain, such that its resistance will cause the current flowing through the device "UD", in the circuit of Fig. 8 to have a value and direction of flow as a result of which "UD" registers the presence of the voltage on the telegraph line. It should be noted that this condition, if maintained for a short predetermined period of time during reception of code combinations of signals, is indicative of a "mark" element.

A "no voltage" condition on the telegraph line, indicative of a "space" element results in de-energisation of the coil of any one of the arrangements of Figs. 1, 2, 4 or 5 and the return of the armature 4 and the piezo-resistive device to the positions in which they are shown in full-lines. In these positions the strain imposed on the piezo-resistive element 8 is relaxed, and so the change in the resistance of the piezo-resistive element results in a change in the magnitude and direction of the current flowing through the device "UD". The device at the new current level and direction of flow therethrough registers the appearance of a "space" element on the telegraph line.

Referring now to the embodiments of Fig. 6 and 7. The coil 18 of the arrangement of Fig. 6 is energised from a suitable power source, via the terminals T3, to generate magnetic flux in the associated magnetic circuit.

The appearance of the D.C. signal potential on the telegraph line at terminals T1 gives rise to a current flow in the coil 21, which in turn generates a force, proportional in magnitude and direction, to this current. This force will cause distortion of the strip 7 to strain the piezo-resistive element 8, whose resistance in this strained condition is such that the magnitude and direction of current flow through the utilisation device "UD", of the circuit of Fig. 8, causes this device to register the appearance of the D.C. signal potential on the telegraph line. The presence of the D.C. signal potential on the telegraph line is indicative of either the standby condition, in which the line is ready to pass code information, or the appearance of a "mark" code element.

Removal of the voltage from the line will indicate the appearance of a "space" element, and the consequent de-energisation of coil 21, will enable the coil 21, the strip 7 and the piezo-resistive element 8, to adopt the positions shown in Figs. 6 and 7.

Relaxation of the strain imposed on the piezo-resistive element 8 changes its resistance, and the resultant change in the magnitude and direction of current flowing in the device "UD" of Fig. 8 will cause it to register the appearance of a "space" element.

Any one of the embodiments shown in Fig. 3, 4, 6 or 7 is suitable for use as a telegraph receiver in systems in which bi-directional current conditions are employed on the telegraph line to indicate the "mark" and "space" elements of a code combination of electric signals, this system is commonly termed "double-current working". In such a system the "mark" condition of an element of a code combination is indicated by the presence of a voltage of, for example, —80 V.D.C. while a "space" condition is indicated by the presence of a voltage of +80 V.D.C.

Referring now to the embodiment of Fig. 3, it can be arranged that the appearance of a transmitted voltage of —80 V.D.C. on the telegraph line will cause the armature 4 of the arrangement to be pivoted anticlockwise about the axis of the pin 16, carrying the piezo-resistive device with it to the new positons in which they are shown in dotted outlines. It is in these positions that the armature 4 and piezo-resistive device rest, and are set to this position by the appearance of a "mark" element on the line which follows the last transmitted element of a message. The first character of any message is preceded by a "space" signal code combination, and thus the transmission of +80 V.D.C. will cause the armature 4 to be pivoted clockwise carrying the piezo-resistive device with it to the positions in which they are shown in full

lines. In the previous position of the piezo-resistive device 8 it was subjected to a compressive strain whilst in the new position it is subjected to a strain causing extension thereof. The resultant change in the resistance value of the element in the circuit of Fig. 8 will change the magnitude and direction of the current flowing through the device "UD", which thus registers the appearance of a "space" element on the telegraph line. A following appearance of a "mark" element will cause the armature 4 and the piezo-resistive element to move back to the positions in which they are shown in dotted outlines. Subjection of the piezo-resistive element 8 to a compressive strain once again will cause its resistance to be changed with consequential change in the magnitude and direction of the current flowing in the device "UD" which will now, register the appearance of the "mark" element on the telegraph line.

Referring now to the embodiment of Fig. 4, the armature 4 and the piezo-resistive device are maintained in the stable position, in which they are shown in full line, by the tension springs 10. It may be arranged that with a negative potential applied to terminals "T1" from the telegraph line, that the armature 4 and the piezo-resistive device will move towards the positions shown in dotted outlines which results from the pivoting of the armature 4 in an anticlockwise direction about the axis of the pin 16. In this position of the piezo-resistive element 8 it is subjected to a compressive strain which changes the resistance value thereof such that the magnitude and direction of current flow in the device "UD" of Fig. 8 registers the appearance of a "mark" element on the telegraph line, or the fact that the line is in the standby condition. Considering the existence of the latter condition, a following appearance of a positive potential on the telegraph line at terminals "T1" will indicate the initiation of a message being passed thereon since the first character of a message is preceded by a "space" element. The armature 4 and the piezo-resistive device in consequence, move towards the positions shown in dotted outline which results from the pivoting of the armature 4 in a clockwise direction about the axis of the pin 16. In this position of the piezo-resistive element 8 it is subjected to strain by extension and the change in the resistance thereof is such that the magnitude and direction of current flow in the device "UD" of Fig. 8 registers the appearance of a "space" element on the telegraph line.

Referring now to the embodiment of Fig. 6 or Fig. 7 employed as a telegraph receiver operating under double current working conditions, and in which the coil 18 of the embodiment of Fig. 6 is energised from a suitable power source via terminals T3. Both arrangements are then dependent on the polarity of the voltage from the telegraph line, applied to terminals "T1", to cause the direction of current flow in the coil 21 to be such that it is deflected to strain the piezo-resistive element 8 either by extension or by compression. For example, −80 V.D.C. on the telegraph line, indicative of the fact that the line is either in the standby condition or the passing of a "mark" element, may be such that the potential at terminals "T1" and the resultant current flow in coil 21, results in a force on the coil 21 which subjects the piezo-resistive element 8 to strain by extension; whilst +80 V.D.C. on the line, indicative of a "space" element, will result in the deflecting force on the coil 21 subjecting the piezo-resistive element 8 to strain by compression. The two different resistance values of the piezo-resistive element 8 in the circuit of Fig. 8 due to the extensive and compressive strains imposed thereupon will thus determine the magnitude and direction of current flow through the device "UD" which then registers the standby condition of the telegraph line or the appearance of "mark" and "space" elements thereon of a code combination being received.

The embodiment of Fig. 6 is also suited to function in a telegraph receiver as a means of sampling the incoming elements of code combinations of signal present on the telegraph line.

In the employment of this embodiment in this manner, the terminals T3, of the fixed coil 18 are connected to the telegraph line, whilst the terminals T1 of the movable coil 21 are connected to a source of sampling pulses. Reversal of the roles of the two coils is practicable, but not necessarily advantageous.

The sampling pulses, which are of short duration, are applied to the movable coil 21 at two repetition rates dependent upon the condition of the telegraph line. During the standby condition the sampling pulses are applied at a high repetition rate, so that the appearance of the first "space" element on the line, which indicates the commencement of the code transmission, will be quickly recognised. Thereafter it is arranged that the sampling pulses are applied once per code element, at fixed time intervals after the commencement of the start signal.

The presence of a D.C. potential on the telegraph line, whether indicative of the standby condition or "mark" code element, will energise the fixed coil 18 and generate the magnetic field in which the moving coil 21 is immersed. Thus each time a sampling pulse is applied to the movable coil 21, during the presence of a signal potential it will experience a transient deflecting force.

In a "single-current" system the appearance of a "space"-element is indicated by a

"no voltage" condition on the line. No current will flow in the fixed coil 18 to generate the magnetic field, and the movable coil 21 will not be deflected when the next sampling pulse is applied.

In a "double-current" system the appearance of a space-element is indicated by a reversal in polarity of the potential on the telegraph line. Consequent reversal of the current flow in the fixed coil 18, to which the line is connected, reverses the direction of the magnetic field in which the movable coil 21 is immersed. The direction of the deflection force on the movable coil 21, which is produced when a sampling pulse is applied during a "double-current" "space" element is therefore opposite to that produced when a "mark" element is sampled.

WHAT WE CLAIM IS:—

1. A transducer arrangement including electro-magnetic means and a piezo-resistive device, said piezo-resistive device being electrically isolated from and mechanically coupled to said electro-magnetic means so that on energisation of the electro-magnetic means the mechanical coupling causes a resistance change to be effected in the piezo-resistive element of said device.

2. A transducer arrangement as claimed in claim 1, and in which said electro-magnetic means is an electro-magnet whose armature is coupled to one side of the piezo-resistive device the other side of which is supported at a fixed point, and in which on a change in the state of energization of the electro-magnet, movement of the armature subjects the piezo-resistive element of said device to strain, which strain causes said resistance change therein to be effected.

3. A transducer arrangement as claimed in claim 2, and in which said armature is pivotally mounted at a point thereon remote from the point at which it is coupled to said piezo-resistive device.

4. A transducer as claimed in claim 3 and in which means is provided to bias said armature to pivot in a direction reverse to that in which it is attracted to the electro-magnet.

5. A transducer arrangement as claimed in claim 1, and in which said electro-magnetic means comprises an arrangement of pole-pieces interconnected by a magnet, in which there is mounted between said pole pieces and surrounded by a coil an armature which is biassed to rest in one of two positions with respect to the pole-pieces, in which one side of the piezo-resistive device is coupled to the armature and the other side thereof supported at a fixed point, and in which on a change in the state of energisation of the said coil attraction between certain one of the pole-pieces and the armature causes the latter to move from said one position to the other whereupon the piezo-resistive element of said device is subjected to strain which causes said resistance change therein to be effected.

6. A transducer as claimed in claim 1 in which said electro-magnetic means comprises an arrangement of pole-pieces interconnected by a magnet, and between which said pole-pieces and surrounded by a coil there is mounted an armature which is permitted to rest in one of the positions with respect to the pole-pieces, in which one side of the piezo-resistive device is coupled to the armature and the other side thereof supported at a fixed point, and in which, dependent on the direction of current flow through the said coil on energisation thereof, attraction between certain ones of the pole-pieces and the armature causes the latter to move from one of said positions to the other or vice-versa, whereupon the piezo-resistive element of said devices is subjected to strain which causes said resistance change therein to be effected.

7. A transducer arrangement as claimed in claim 6 in which means is provided to cause said armature to rest in another position intermediate said two positions and in which, dependent on the direction of current flow through said coil on energisation thereof, attraction between certain ones of the pole-pieces and the armature causes the latter to move from said intermediate position to one or the other of said two positions, whereupon the piezo-resistive element of said device is subjected to strain which causes said resistance change therein to be effected.

8. A transducer arrangement as claimed in claim 1 in which said electro-magnetic means comprises a magnet in the field of which a coil is supported by one side of the said piezo-resistive device the other side of which device is supported at a fixed point, and in which said coil, on energisation thereof, is subjected to a deflecting force by said magnet which said deflecting force imposes a strain on the piezo-resistive element of said device to cause said resistance change therein to be effected.

9. A transducer arrangement as claimed in claim 1 in which said electro-magnetic means comprises an electro-magnet in the field of which a coil is supported by one side of the said piezo-resistive element the other side of which element is supported at a fixed point, and in which on energisation of both the electro-magnet and the said coil the coil is subjected to a deflecting force which imposes a strain on the piezo-resistive element of said device to cause said resistance change therein to be effected.

10. A transducer arrangement substantially as described herein with reference to any one of Figs. 1 to 9 of the accompanying drawings.

11. A telegraph receiver for single-current operation including the transducer arrange-

ment claimed in any one of claims 1, 2, 3, 4, 5, 7, 8 or 9.

12. A telegraph receiver for double current operation including the transducer arrangement claimed in any one of claims 1, 2, 6, 7, 8 or 9.

13. In a telegraph receiver a signal sampling device including the transducer arrangement claimed in claim 9.

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Chartered Patent Agent,
For the Applicants.

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1019861 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG.1.

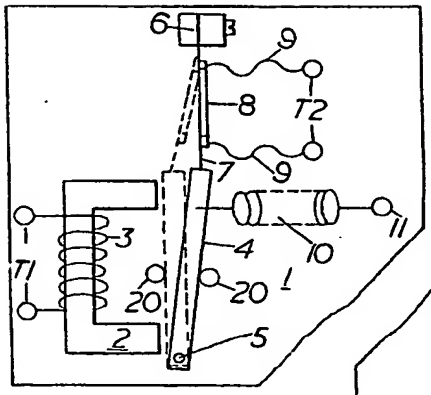


FIG.2.

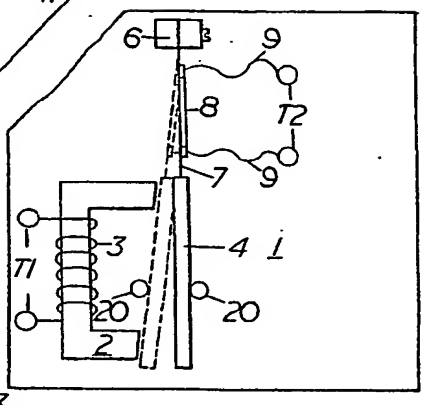


FIG.3.

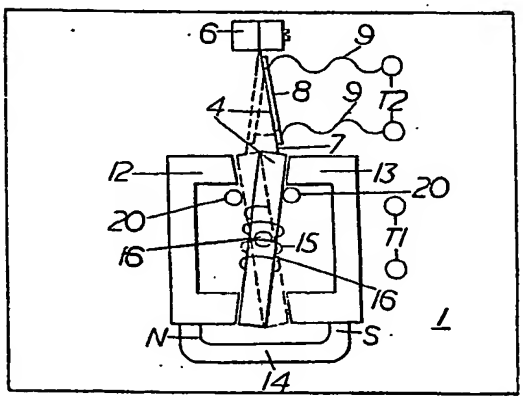


FIG4

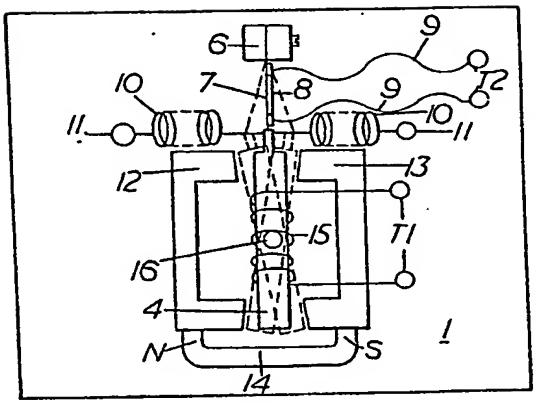
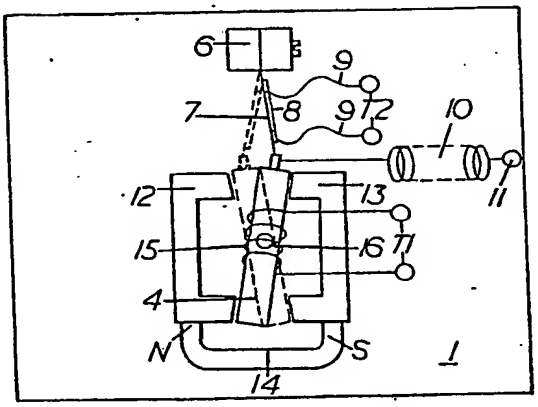


FIG.5.



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Sheets 2 & 3

FIG.6.

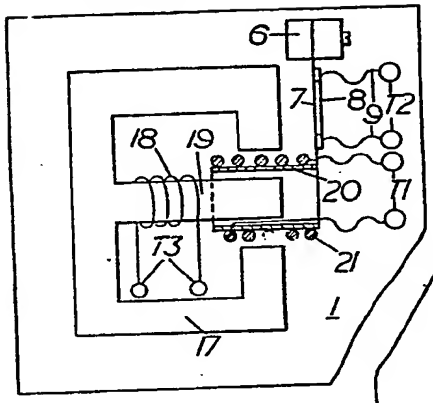


FIG.7.

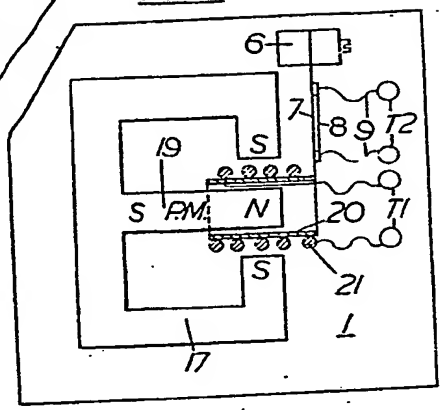
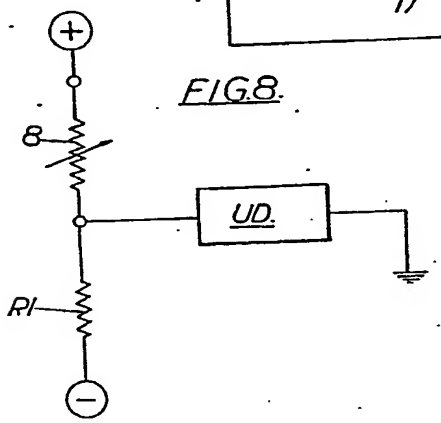


FIG.8.



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Sheets 2 & 3

FIG.4

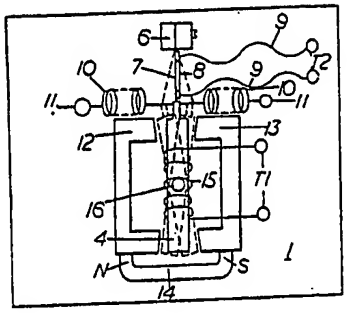

FIG.5.

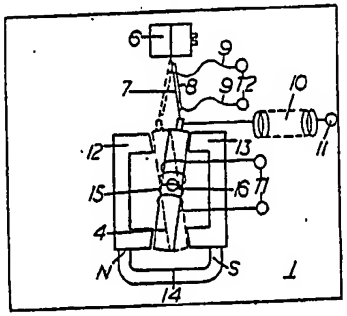

FIG.6.

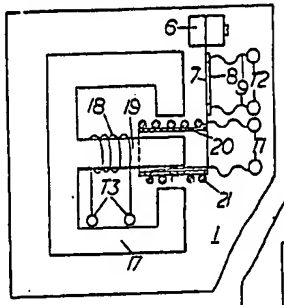

FIG.7.

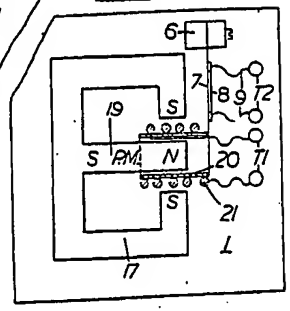

FIG.8.